International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, Volume 2, Issue 9, September 2012)

Investigation of land subsidence in Southern Mahyar Plain in Isfahan province, Iran

Salehi[1], R. Ghafoori[1] M., Lashkaripour[1], G.R. and Dehghani[2], M.

[1] *Department of Geology, Faculty of Sciences, Ferdowsi University of Mashhad*
[2] *Department of Civil and Environmental Engineering,School of Engineering, Shiraz University*

***Abstract*— Land subsidence is one of the environmental hazards in which various mechanisms take part in its formation and development. Excessive extraction of groundwater has caused severe land subsidence and earth fissures in the Southern Mahyar Plain located in Isfahan province in the peripheral part of Iran's central desert. In the last decades, fast agricultural expansion coupled with rapid population growth has tremendously increased pressure on the ground water resources. This paper deals with the relation between declining of ground water level, land subsidence and earth-fissure based on the available data in Southern Mahyar Plain. Based on field data, the temporal and spatial distribution of land subsidence is investigated and the causes for earth fissures are analyzed. Collected data using peizometric wells on the plain surface shows that the mean drop of water level in the period of 12 water years was 6m. Moreover, investigation of groundwater level fluctuations and compiling iso-depth maps in the district of the plain confirmed sharp drop of groundwater level. The areal distribution of the land subsidence is closely related to the cones of depression in the main exploited aquifers. In addition, field surveys in the study area indicated that fissures and cracks due to subsidence occur in the peripheral part of plain that inflicted severe losses to the agricultural lands. In this study, Interferometric SAR technique with the aid of radar image of the satellite ENVISAT was used for the determination of the area affected by subsidence and investigation of surface undulation in short-term and long-term periods. Also by analysis of maximum time series, the mean rate of subsidence in the period of 2003-2006 was calculated to be 8.2 cm per year..**

***Keywords*—subsidence, groundwater, Southern Mahyar Plain.**

I. INTRODUCTION

Land subsidence is a gradual settling or sudden sinking of the earth surface associated with negligible horizontal displacements [2].

Subsidence due to the drop of groundwater level is a universal hazard that caught attention throughout the world. One of the most important factors of subsidence is the drop of groundwater level that caused subsidence in many plains inside Iran in the recent decades.

There are a variety of methods available to monitor land subsidence. They include vertical extensometers, baseline and repeated surveys of benchmarks using Global Positioning System (GPS) or conventional survey methods, and Interferometric Synthetic Aperture Radar (InSAR). Interferometric SAR technique (InSAR) is the most modern technology for the subsidence surveys. The technique of (InSAR) is uniquely suited to monitor elastic and inelastic response of aquifer systems to changes in groundwater levels, providing new insight into the role of geological structures and lithological parameters in plain aquifers [1,7,3,8]. With its wide spatial coverage (∼ 104 km^2), fine spatial resolution (∼ 102 m^2), and high accuracy (∼ 1 cm), InSAR offers new capabilities to measure surface deformation caused by aquifer discharge and recharge at an unprecedented level of detail never before possible with techniques like GPS and leveling [7,3,9]. Also, new methods and techniques such as advanced geographic positioning and radar have been applied in some plains of the Iran including the Neyshbour plains in the Khorasan-e-Razavi province [5] and the Mashhad plains [6,9].

This paper focuses on the study area Southern Mahyar Plain SE of Isfahan, which bounded on the north by the southern part of the Kolah Ghazi Mountains, with trending NW-SE as shown in figure 1. It is a broad sedimentary basin composed primarily of Quaternary-Neogene alluvial deposits [10]. Annual rainfall in the area is estimated to range from 100 to 150 mm yr^{-1}, occurring mainly during spring and winter seasons.

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, Volume 2, Issue 9, September 2012)

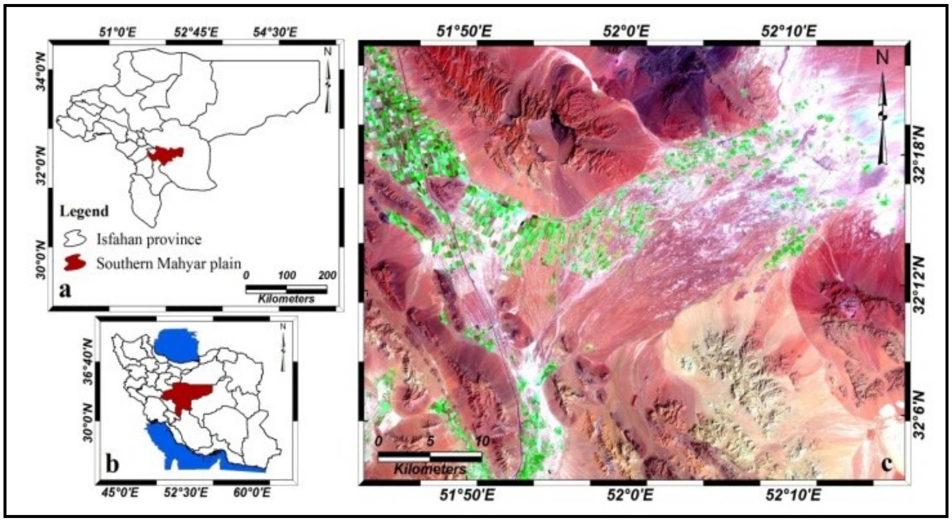

Figure 1. Location of the Southern Mahyar plain in Isfahan, Iran (a & b), LANDSAT 7 ETM+ color composite image (c) of the Southern Mahyar plain.

II. HYDROGEOLOGICAL SETTING

According to the previous studies, the aquifer of the Southern Mahyar plain is an unconfined type which located between two relatively parallel heights with general trend of southeast-northwest. The heights in the vicinity of the plain are formed predominately from carbonate rocks such as limestone, dolomite lime and marl lime. Karstic holes with small extension are visible in the surface of limestone layers. Available sediments in the Southern Mahyar plain can be considered to be formed from direct sedimentation of floods and streams. They come from the northern and southern heights and include relatively compact alluvial terraces with low transmissivity, porous limestones and aeolian and fluvial sediments. They form the aquifer for groundwater resource in this area. Investigation of groundwater level undulation takes an important part in this study regarding to the causes of land subsidence. Therefore data from groundwater level changes during 1997 to 2009 have been used from the piezometric wells in the Southern Mahyar plain. According to the unit hydrograph, despite seasonal fluctuations, groundwater level of the plain show descending trend and mean drop of the plain's groundwater level in the 12 years period was found to be 50 cm, as shown in figure 2 Maximum drop of groundwater level about 3 m belongs to 1990s.

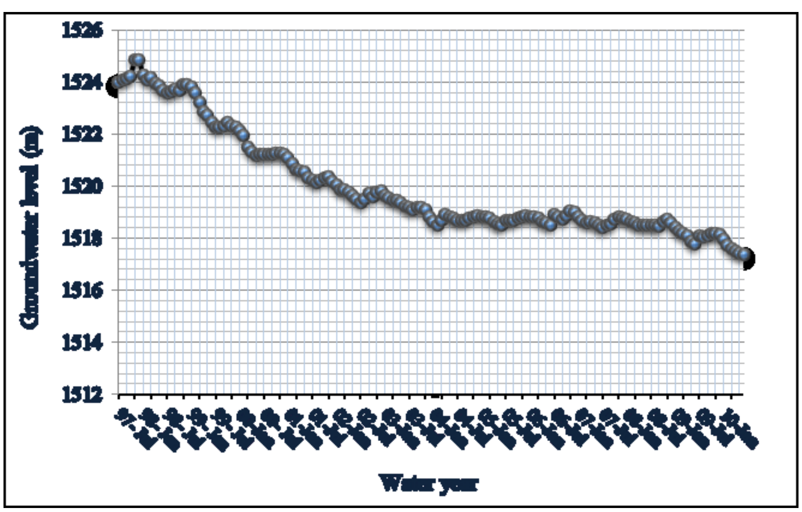

Figure 2. Unit hydrograph groundwater level change in Southern Mahyar Plain.

III. Results Of Groundwater Level Studies

The map of groundwater level in March 2010 was compiled using statistics of the available piezometers data in the plain, Figure 3. This figure shows the situation of groundwater level elevation relative to free sea level in the various part of the plain. Based on this map the general trend of groundwater is from the southern heights towards the plain and most of groundwater enter the plain from the south-east. In the north-west of plain a drop cone was formed. This cone indicates the flow of groundwater from all directions toward this position due to high density of the utilization wells in the region. In the south-east the map shows the groundwater level rising because of the aquifer recharge from alluvial fans of the southern heights. Decrease of contours in the eastern part of the plain indicates the hydraulic gradient trends from the central and western parts towards this direction.

Isodepth map of groundwater level was prepared using statistical data of available piezometers in the plain and contours of 10 m, Figure 4. According to this map, contact depth of groundwater level in this plain changes from up to 130 m in the piezometers located in the north-west of the region to minimum 10 m in the eastern parts of the plain. Isodepth map indicate that the depth of groundwater level is decreased in the general direction of the plain, namely from the west towards the east. Deep groundwater level, around the depth of 130 m, in the northwest is apparently due to the concentration of utilization wells in this part of the region. The depth of groundwater level in the southeastern piezometer was about 10m, due to the inward floods from the southern heights of the plain. In the central parts of the plain, there are contours of up to 50 to 70 m that lead to the contours of minimum 10 m in the eastern and northeastern parts of the study area. This decrease in the depth of groundwater level can be due to lower concentration of utilization wells and direction of topographic dip in these areas.

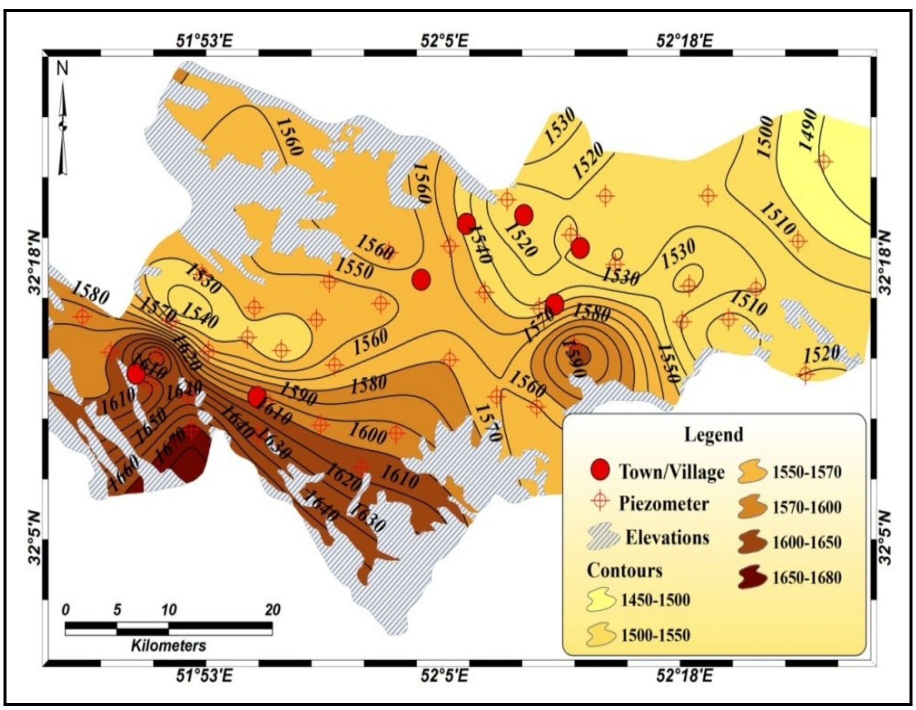

Figure 3. The map of groundwater level in study area, March 2010

International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (ISSN 2250-2459, Volume 2, Issue 9, September 2012)

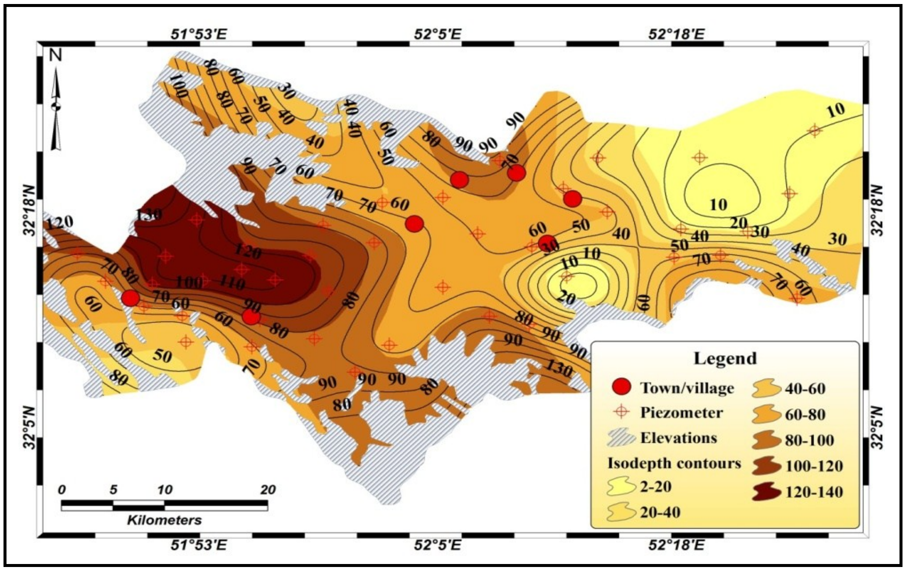

Figure 4. Isodepth map of groundwater level in study area, March 2010

IV. DISCUSSION

The natural features of land subsidence are the formation of fissures and cracks in the land and structures in the region. The predominant land survey in this study was the survey of position and strike of fissures and cracks resulted from land subsidence using global positioning system (GPS) in the various parts of the region. These surveys indicate that fissures propagation isn't monotonous throughout the plain surface. They are appearing as a bundle of parallel fissures in the northwestern parts of the plain which their aperture wide changes from several centimeters to more than one meter wide with up to 20 m depth. Density and depth of these fissures decrease in the northern parts of the plain (agricultural lands in the heels of the Kolah Ghazi heights). The subsidence features in the study area was shown in figure 5.

To find the relationship between subsidence and drop of groundwater level in the Southern Mahyar Plain, position of fissures and cracks due to land subsidence were overlaid on the isodepth map of groundwater level, Figure 6. According to the theory [4], in the aquifers with long term withdrawals and withdrawal volume more than recharge, effective stress increases which causes deformation and compaction of the sediment that finally lead to fissure formation.

So it can be said that reckless withdrawal of groundwater and continuous drop of groundwater level in the study area, at first, led to land subsidence and then with the increase of subsidence, fissures formed which are objective representations of subsidence in the region.

Figure 5. Two examples of surface fissures in Southern Mahyar Plain (a and b)

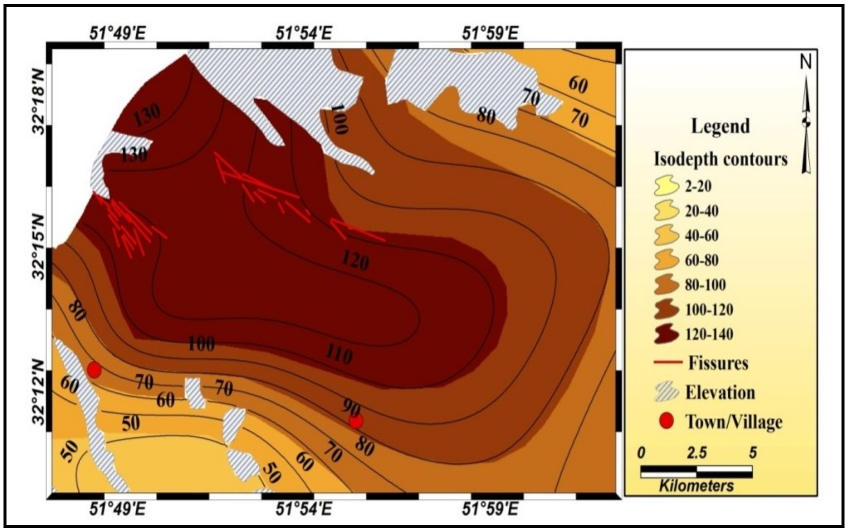

Figure 6. positions of fissures and cracks due to subsidence in study area

V. CONCLUSIONS

In this study, groundwater contour map and iso depth map of groundwater level were compiled after investigation of groundwater level undulation in the study area. These maps, unanimously, indicate sharp drop of groundwater level in the southern part of the plain vicinity of the Kolah Ghazi heights to the nearby of the central parts of the plain. Using Interferometric Synthetic Aperture Radar (InSAR) technique, the affected extent of the subsidence risk in the period of 2003 to 2006 was determined and the rate of land surface deformation was estimated in the southern Mahyar plain. The maximum subsidence from the time series analysis for the entire region was found to be 8.2 cm per year.

The results of these studies and overlay of the compiled maps with the position of subsidence features confirm the occurrence of this phenomenon in the consequence of sharp drop of groundwater level in the study area. Therefore land subsidence and formation of fissures and cracks inflicted severe losses to the agricultural lands located in the heels of the Kolah Ghazi and in the northwestern of the southern Mahyar plain.

VI. ACKNOWLEDGMENTS

We thank the European Space Agency (ESA) and Remote Sensing group of the K. N. Toosi University of Technology for providing the ENIVSAT ASAR data and GAMMA software, respectively. The authors also thank the Esfahan Regional Water Board, for piezometers wells' data.

REFERENCES

[1] Amelung, F., Galloway, D. L., Bell, J. W., Zebker, H. A. and Laczniak, R. J. 1999. Sensing the ups and downs of Las Vegas InSAR reveals structural control of land subsidence and aquifer-system deformation, 483–486.

[2] Bates, R. L., and Jackson, J. A. 1980. Glossary of Geology. American Geological Institute. Second edition, Falls Church, Virginia.

[3] Bell, J. W., Amelung, F., Ramelli, A. R. and Blewitt, G. 2002. Subsidence in Las Vegas, Nevada, 1935–2000, New Geodetic Data Show Evolution, Revised Spatial Patterns, and Reduced Rates, 2002, 155–174.

[4] Burbey T. J. 2002. The influence of faults in basins-fill deposits on land subsidence, Las Vegas Valley, Nevada. *USA*, Hydrogeology Journal, 525–538.

[5] Dehghani, M., Valadan Zoej, M., Entezam, I., Mansourian, A. and Saatchi, S. 2009. "InSAR monitoring of progressive land subsidence in Neyshabour, northeast Iran", *GJI*, Geodesy, 47-56.

[6] Dehghani, M., Zoej, M. J., Saatchi, S., Biggs, J. Parsons, B. and Wright, T. 2009b. "Radar interferometry time series analysis of Mashhad subsidence ", Journal of the Indian Society of Remote Sensing, 147-156.

[7] Hoffmann, J., Zebker, H.A., Galloway, D.L. and Amelung, F. 2001. Seasonal subsidence and rebound in Las Vegas Valley, Nevada, observed by synthetic aperture radar interferometry, Water Resour, 1551–1566.

[8] Motagh, M., Djamour, Y., Walter, T. R.,Wetzel, H. U., Zschau, J. and Arabi, S. 2007. " Land subsidence in Mashhad Valley, northeast Iran", results from InSAR, leveling and GPS, Geophysical Journal International, 518-526.

[9] Schmidt, D.A. and Burgmann, R. 2003. " Time dependent land uplift and subsidence in the Santa Clara valley, California, from a large InSAR data set " , J. geophys.

[10] Zahedi, M. 1976. Geological Map of the Shahreza, scale 1:100,000. Geological Survey of Iran.